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Engineering design matrices illustrate the relationships among waste application rate, application frequency, and waste degradation rate, and the effect of these parameters on stabilized concentrations during the active life of a unit were developed. Waste degradation half-life and waste application frequency were observed to have greater influence in determining the stabilized weight percentage of oil in the treatment soil than waste application rate. A three-dimensional graph was developed as an example of how design matrices can be used as engineering/management aids for petroleum land treatment site design and operation.

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Review and Evaluation of Current Design and Management Practices for Land Treatment Units Receiving Petroleum Wastes

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ABSTRACT

Land treatment is categorized in the Resource Conservation and Recovery Act of 1976 (RCRA) as one of the land disposal options for managing hazardous wastes. Land treatment relies on detoxification, degradation, and immobilization of hazardous waste constituents within the defined treatment zone to ensure protection of surface water, groundwater, and air. Under the authority of Subtitle C of RCRA, the U.S. Environmental Protection Agency has promulgated regulations governing the treatment of hazardous wastes in land treatment units (40 CRF, Part 264, Subpart M, July, 1982).

This paper describes the land treatment practices used by petroleum waste land treatment facilities in the U.S. Information obtained for thirteen full-scale land treatment facilities included types of waste land treated, characterization of land treated wastes, waste application rates (loading rates), waste application frequencies, and management practices used at the treatment units.

Engineering design matrices which illustrate the relationships among waste application rate, application frequency, and waste degradation rate, and the effect of these parameters on stabilized concentrations during the active life a unit were developed. Waste degradation half-life and waste application frequency were observed to have greater influence in determining the stabilized weight percentage of oil in the treatment soil than waste application rate. A three-dimensional graph was developed as an example of how design matrices can be used as engineering/management aids for petroleum land treatment site design and operation.

INTRODUCTION

Land treatment is the controlled application of liquid, solid, and semisolid wastes to the upper zone, usually the top 6 to 12 inches, of a soil system for achieving treatment and simultaneous safe ultimate disposal. Objectives of land treatment are: 1) to prevent off-site migration of hazardous constituents via migration to ground and surface waters and transport through the atmosphere, and 2) to render the wastes less or non-hazardous through treatment. Treatment includes the processes of degradation, transformation, and immobilization of hazardous constituents in a soil/waste mixture.

Land treatment of petroleum industry wastes involves the immobilization of metal constituents and the immobilization and biodegradation of organic constituents. Land treatment has been used as a waste management technology by the U.S. petroleum industry for more than 25 years.

Figure 1 shows the location of petroleum industry land treatment facilities in the United States. The U.S. Environmental Protection Agency (EPA) has given an estimate of 100 land treatment facilities for the U.S. petroleum industry (1).

This paper is based on a subset of thirteen presently operating petroleum refinery facilities that represent the geographical distribution of refineries in the U.S. Information was obtained specifically with respect to factors addressed by the EPA concerning regulations governing the treatment of hazardous waste in land treatment facilities as specified in 40 Code of Federal Regulations (CFR), Part 264, Subpart M, July 1982, even though no full-scale facility has been issued a permit to land treat hazardous waste at this time. The information obtained included:

- types of wastes land treated;
- characterization of wastes, including specific inorganic and organic constituents, and of waste treatment sites;
- waste application methods, rates, and frequencies; and
- operation and management of land treatment units.

A design and management matrix was developed to illustrate the effects of design factors (application rates, application frequencies) and site factors (biodegradation half-life for the soil/waste mixture) on waste treatment. Waste treatment was characterized as the stabilized oil/soil concentration resulting from long-term waste application. The objectives of this paper are to summarize the information obtained and to indicate the integrated effects of design and management factors on petroleum waste treatment.

CURRENT APPROACH TO LAND TREATMENT IN THE PETROLEUM INDUSTRY

Waste Characterization

Specific waste streams that are land treated at the thirteen facilities are summarized in Figure 2. Four petroleum wastes most frequently land treated, in decreasing order of frequency, are API separator sludge, slop oil emulsion solids, dissolved air flotation froth (DAF), and waste activated sludge.

The physical properties of wastes that are land treated at the facilities are presented in Figure 3. The physical characterization of the wastes ranged from a minimum oil concentration of 0.1 percent with 96 percent water and 3.9 percent solids to a maximum oil concentration of 17.4 percent with 38.6 percent water and 44 percent solids. The mean physical properties of the wastes were 12 percent oil, 70 percent water, and 18 percent solids.

Specific inorganic and organic hazardous constituents identified in petroleum wastes are presented in Figures 4 and 5, respectively.

Climatic, Soil, and Physical Characterization

Climatic, soil, and physical site characteristics for individual facilities are presented in Tables 1 through 4, respectively. Climatic characteristics listed in Table 1 indicate a large range in atmospheric temperatures, relative humidity, and precipitation for the thirteen sites. Soil characteristics listed in Table 2 also indicate a large range in parameters that may affect land treatment, with the exception of pH values, including permeability, erodibility, texture, and cation exchange capacity. Physical site characteristics listed in Tables 3 and 4 include the ranges in depth to bedrock, water table, and usable aquifer, and identify site modifications for each facility. Thus, the sites for the thirteen facilities represent a wide variety of climate, soil, and physical

FIGURE 1. Location of Petroleum Industry Hazardous Waste Land Treatment Facilities in the United States (1)

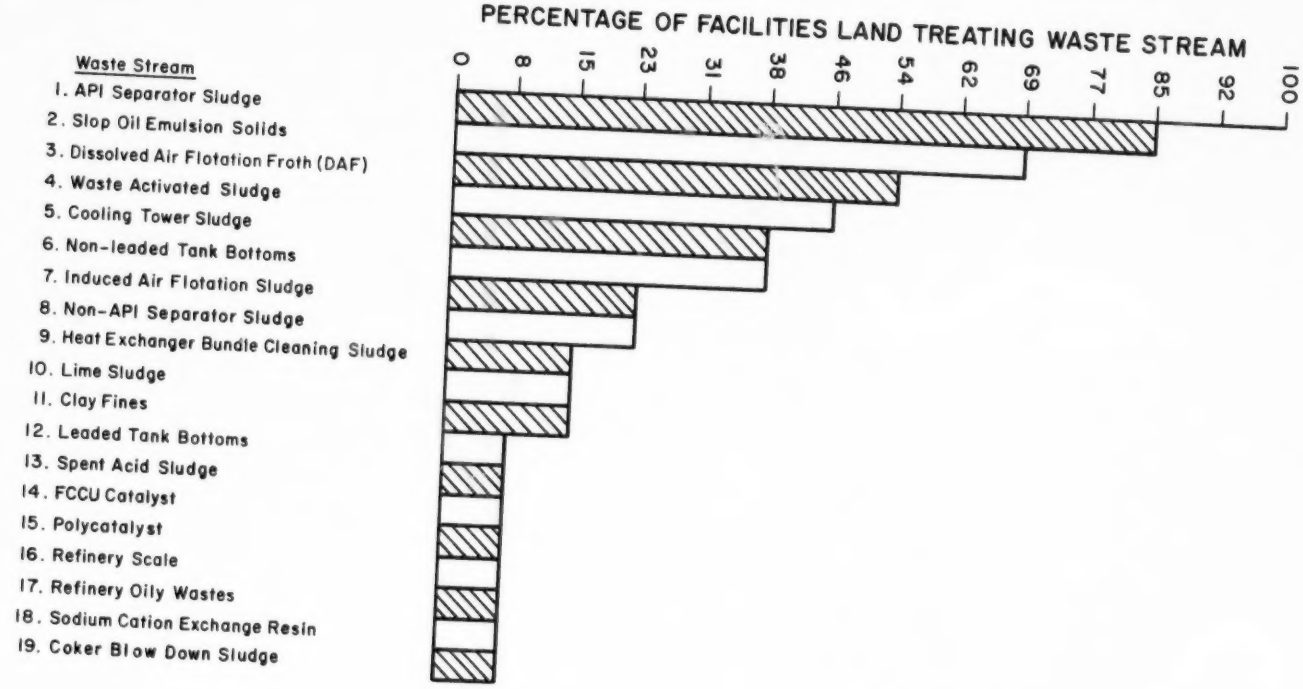

FIGURE 2. Specific Waste Streams Treated at the Thirteen Petroleum Land Treatment Facilities

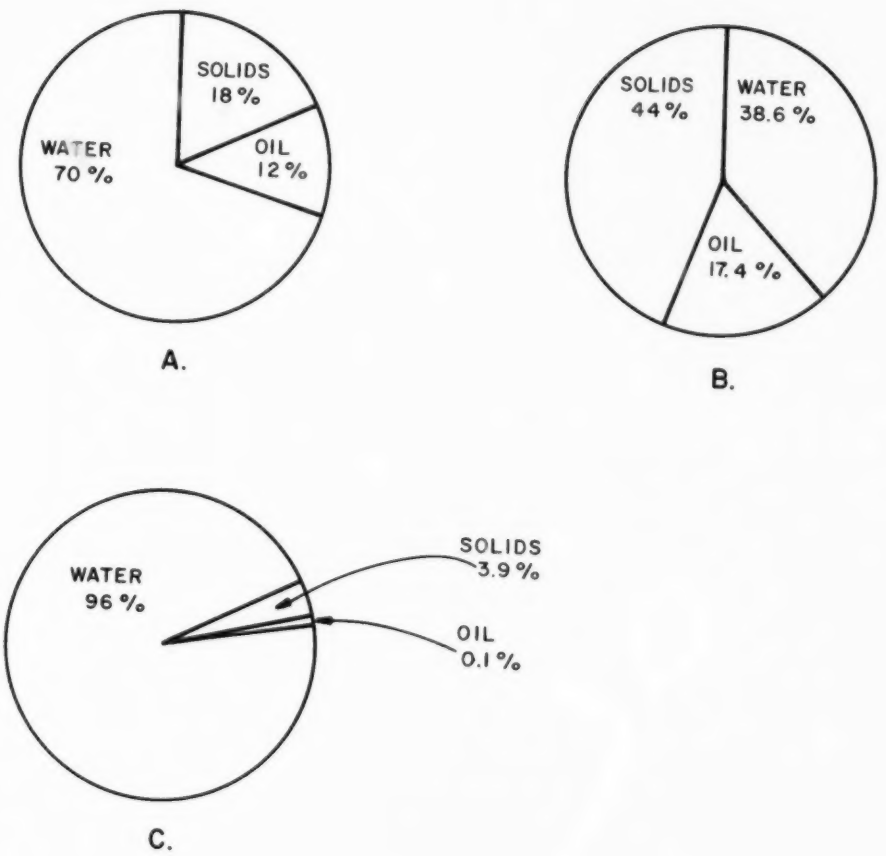

FIGURE 3. Physical Characterization of Land Treated Wastes in the Survey of Thirteen Petroleum Refinery Facilities: A) Facility with a Mean Oil Concentration, B) Facility with a Maximum Oil Concentration, and C) Facility with a Minimum Oil Concentration.

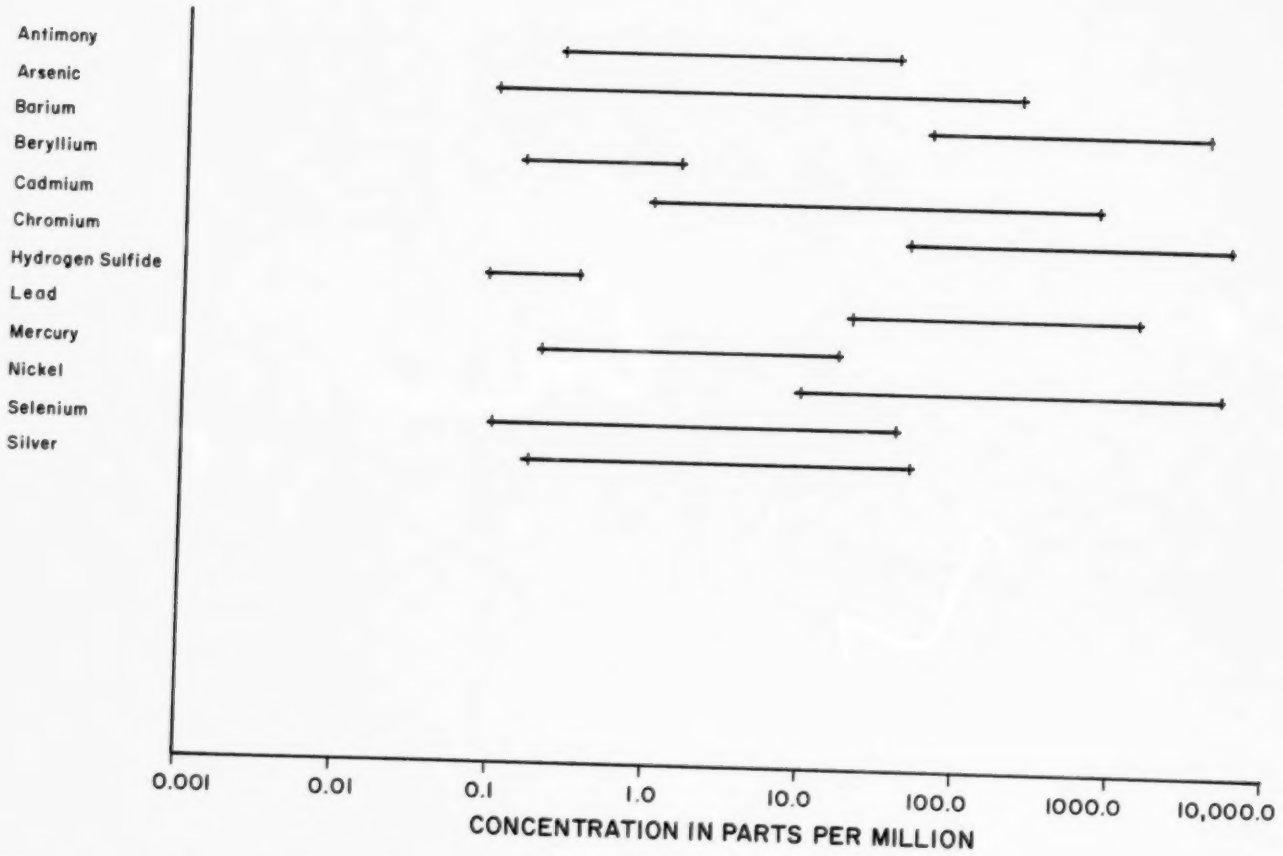

FIGURE 4. Range of Hazardous Inorganic Constituent Waste Concentration for Thirteen Land Treatment Facilities

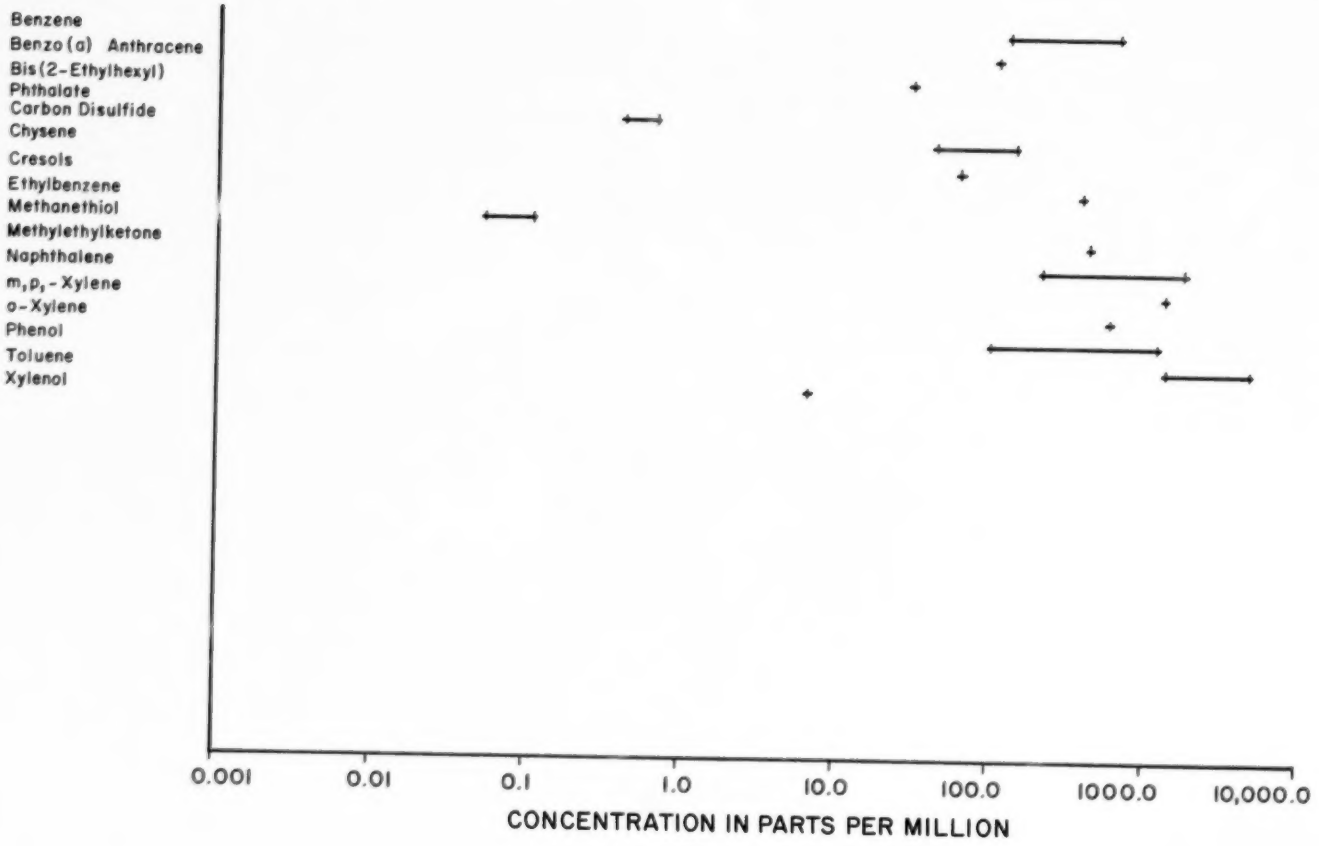

FIGURE 5. Range of Hazardous Organic Constituent Waste Concentrations for the Thirteen Land Treatment Facilities

TABLE 1.
Climatic Characteristics of Land Treatment Facilities

Parameter	Facility Code 01	02	03	04	05	06
Atmospheric Temperature (°C)						
Average Annual Minimum	4	10	-15	-18	12	-8
Average Annual Maximum	14	32	24	32	21	31
Daily Minimum	-27	-18	-26	-34	-1	-13
Daily Maximum	40	43	46	40	43	37
Relative Humidity (%)						
Average Annual	74	80	-*	70	70	50
Extreme Daily	100	100	-	100	-	100
Annual Precipitation (meters)						
Total	0.8	1.5	0.9	0.7	0.3	0.7
Snow	1.0	0	0	1.2	0	0.1
Rainfall Intensity (meters)						
24 Hour Maximum	0.2	0.3	-	-	0.2	0.1
Average Number of Days of Rain and Snow						
0.05 Meter Rain or Greater	-	16	-	-	1	0
0.0254 Meter Snow or Greater	-	0	-	-	0	1

Parameter	Facility Code 07	08	10	11	12	13
Atmospheric Temperature (°C)						
Average Annual Minimum	2	-	>10	-3	-5	27
Average Annual Maximum	14	-	-	20	22	43
Daily Minimum	-39	-	-	10	-	4
Daily Maximum	41	-	-	31	-	48
Relative Humidity (%)						
Average Annual	54	-	-	65	-	40
Extreme Daily	71	-	-	93	-	60
Annual Precipitation (meters)						
Total	0.4	1.3	0.1	0.8	0.4	0.05
Snow	1.4	-	-	-	0.05	0
Rainfall Intensity (meters)						
24 Hour Maximum	0.06	-	-	0.04	0.08	0.05
Average Number of Days of Rain and Snow						
0.05 Meter Rain or Greater	2	-	-	-	0	0
0.0254 Meter Snow or Greater	20	-	-	-	10	0

*Information was not available.

TABLE 2.
Soil Characteristics of Land Treatment Facilities

Parameter	Facility Code 01	02	03	04	05	06
Surface Soil						
Permeability (m/hr)	4.3×10^{-7}	3.8×10^{-2} to 3.8×10^{-4}	-	-	0.9	3.6×10^{-4} to 3.6×10^{-3}
Erodibility	Slight	Slight	Moderate	Moderate	Moderate	Slight
Texture	Clay, silty mottled, gray/ brown, wet	Varies, silt, sandy silt, & silty sand	Very fine sand & silt	Sandy loam	Dune sand	Glacial till, silty clay
Cation Exchange Capacity (meq/100 g)	17.0-27.6	17.0-39.0	9.1	-	Estimated low value	20
pH	7.2- 7.8	8.0	6.4	7.6	7-8	6
Subsurface Soil						
Permeability (m/hr)	1.7×10^{-6}	3.8×10^{-4} - 3.8×10^{-6}	7.2×10^{-4}	3.6×10^{-2}	0.9	3.6×10^{-4}-3.6×10^{-3}
Texture	Clay, silty with sand, brown/gray	Clays and sandy clay	Mostly silt and clay	Sandy loam glacial till	Moderately fine sand. Soil at 1-3 ft. below grade is approx. 95% compacted	Silty clay

Parameter	Facility Code 07	08	09	10	11	12	13
Surface Soil							
Permeability (m/hr)	1.5×10^{-3}	3.6×10^{-6}	-	2×10^{-6} - 2×10^{-5}	-	3.6×10^{-6}	-
Erodibility	Slight	Slight	Slight	-	-	Slight	Slight
Texture	Fine & coarse grain soil	Silty clay	Sandy clay loam	Clay	-	Clay loam	Clay
Cation Exchange Capacity (meq/100 g)	26.9-28.5	11.2	20-30	35	22	20-35	-
pH	7.7-8.7	7.6	7	7.4-8.3	5.5	6.8-7.2	7
Subsurface Soil							
Permeability (m/hr)	1.5×10^{-3}	3.6×10^{-6}	-	-	-	3.6×10^{-6}	3.6×10^{-6}
Texture	Fine & coarse grain soil	Clayey soils	-	-	-	Clay loam	Clay

TABLE 3.
Physical Site Characteristics for Land Treatment Facilities 01 Through 06

Parameter	Facility Code 01	02	03	04	05	06
Location/distance (km) from refinery	4.8 km N.E.	32. km south	0.8 km N.E.	On site	Within refinery	-
Depth to bedrock (m)	37	-	-	18	-	30
Depth to seasonally high water table (m)	37	0.9	-	15	19	2
Depth to usable aquifer	37	79	152-183	76	No usable aquifer	9
Previous land use, if any	None	Not known	Wooded, with no use	Inactive Refinery Property	Cultivated landfarm	None
Is the site						
Wet land	No	No	No	No	No	No
Adjacent to wet land	No	Yes	No	No	No	No
Subject to flooding	No	Yes, 0.6 m/24 hr*	No	No	No	No
Site Modifications Run-on/run-off controls roadway, etc.	Removed trees, rocks, etc. tilled sloping to central point, land raised by adding topsoil. Constructed 1.2 m high dike and road around the sites.	Site is designed to permit solid material to settle and allow the carriage water to be removed back to the wastewater treatment facility.	When site was opened trees were removed, diking was built, and roads were constructed	Road construction elevated	Landfarm constructed in two phases: "sloped portion" and "flat portion." Flat portion approx. 1.9 ha topsoil added to establish active area (0.254 m). Dirt access road running lengthwise. Ground graded to 2% slope from center out and 0.5% slope lengthwise. Berms constructed to prevent run-on/run-off. Top soil added to one side of landfarm approx. 1.0 ha x 0.254 m.	Roads, terracing, run-on and run-off control

*100 year flood depth

TABLE 4.
Physical Site Characteristics for Land Treatment Facilities 07 Through 13

Parameter	Facility Code 07	08	09	10	11	12	13
Location/distance (km) from refinery	25	-	On site	8	-	-	1.6
Depth to bedrock (m)	7.6	15.2	-	-	-	18.2	-
Depth to seasonally high water table (m)	1.5	2.4	-	3.6	18	4.9	-
Depth to usable aquifer	-	30-122	-	15.2	18	8.5	-
Previous land use, if any	Dry land farming and grazing	Idle land	Dredge spoil area for dredging from process water reservoir	Rice Farm	Pasture	Dry land farming	Unirrigated desert land
Is the site							
Wet land	No	No	No	-	No	No	No
Adjacent to wet land	No	No	No	-	No	No	No
Subject to flooding	No	No	Yes/0.33 m*	-	No	No	No
Site Modifications Run-on/run-off controls roadway, etc.	Contouring, leveling, grading, dike construction, road construction.	Installed containment dikes, all weather roads, plus grading and terracing to provide subdivided and gently sloped (3%) application areas.	Addition of top soil.	Soil slope is level. Site divided into eight subplots. Diking and grading each subplot. Construction of surface drainage ditches to collect runoff. Construction of a sump and pipeline to transport stored runoff to refinery for subsequent discharge. Constructed pipeline from refinery to site for composite sludge transportation. Constructed a 25,000 barrel storage tank (4-6 month storage). Constructed roads and installed chain-link fencing around treatment site.	3.5% slope, roadways to allow vacuum truck entry, area is bermed to prevent escape of runoff, runoff is collected and returned to waste water treatment plant via process sewer.	Grading and road/dike construction.	Diked area surrounding natural clay.

*100 year flood depth.

site characteristics that are adequate for land treatment of petroleum refinery wastes.

Operation/Management Characterization

Facility operational characteristics are presented in Tables 5 and 6. Land treatment areas for the thirteen facilities ranged from 2.8 hectares to 85 hectares, and waste incorporation depth ranged from 0.15 meters to 0.66 meters. The number of months the facilities were actively used per year varied from 6 months (colder climates) to 12 months (warmer climates). Waste application methods included spraying, surface spreading, subsurface injection, and vacuum truck hose application. Maximum waste application rates ranged from 0.004 weight percentage of oil in soil (oil/soil concentration) per application to 8 percent oil/soil concentration per application. Waste application frequencies varied from daily to yearly depending upon waste generation. Approximately 70 percent of the facilities added amendments to the soil for waste degradation enhancement, including NPK fertilizer and lime.

Design Matrix for Evaluating Treatment

Major design and site factors affecting waste treatment include waste application rate and application frequency, and waste degradation rate as influenced by site/soil characteristics. Waste application rate, or loading rate, is a function of oil concentration in the waste and the land area for waste treatment, assuming a conventional 15 cm depth of incorportion. Waste application frequency is generally a function of production rate and waste quantity. Waste degradation rate may be a function of site and soil characteristics including climatic conditions, soil temperature and moisture, soil texture and chemistry, and operation/management practices (2). Degradation rate may also be a function of the loading rate, especially when the waste exerts a toxic effect on microorganisms (3). Degradation rates are generally expressed as half-life, or the time required to decrease the original concentration by one-half, and may incorporate all of the site/soil factors identified above. Degradation includes biodegradation as the primary mechanism, but may also include some volatilization losses. Degradation kinetics, expressed as half-lives, are generally modeled based on zero order or first order reactions.

A design matrix was developed to illustrate an approach for evaluating the combined effects of design factors, including waste application rate and application frequency, and site factors, evaluated as biodegradation half-life, on waste treatment. Waste treatment was characterized as the stabilized, steady-state, oil/soil concentration resulting from long-term, repeated, waste application. Waste application rates and application frequencies for the facilities evaluated are listed in Tables 5 and 6. Due to the dearth of information obtained concerning oil degradation kinetics for the facilities evaluated, a zero order kinetic model was used with literature values for half-lives. A range of half-lives was used in order to evaluate the effects of site/soil characteristics on treatment. The U.S. EPA (4) described the use of zero order kinetics and half-lives for land treatment systems treating petroleum wastes. Overcash and Pal (5) also described oil degradation in soil systems in zero-order kinetic terms. However, other findings for oil and especially for individual constituents suggest that first order reactions can also be used to represent degradation reactions in land treatment systems (6, 7, 8, 9). Zero order kinetics was used because it is one conventional approach for handling rate data and for describing oil degradation in land treatment systems. A similar design matrix could be developed based on first order kinetics to illustrate the effects of design factors and site factors (temperature) on waste treatment. Additional factors that may influence the actual rate of degradation used in developing a design matrix include acclimation of the soil microbial community to the waste and a possible overloading of the biological community at high loading rates or loading frequencies. The primary purpose for applying a kinetic approach to the data obtained, and for using a

TABLE 5.
Operational Characteristics for Land Treatment Facilities 01-06

Parameter	Facility Code					
	01	02	03	04	05	06
EPA region	V	VI	VI	V	IX	X
Treatment area (ha)	8	85	2.8	6	4	8
Zone of waste incorporation (depth, meters)	0.2-0.3	0.46	0.15	0.66	0.25-0.30	0.30
Reported waste application rates (maximum)	472 m^3/ha/ appl.	265 metric tons waste/ha/appl.	786 m^3/ha/ appl.	5 kg/m^2/ appl.	112 metric tons/ha/ appl.*	70 metric tons/ha/ appl.
Number of months site actively used per year	6-7	12	7	7-8	9-12	12
Frequency of waste application	Monthly	Yearly per plot	Yearly	Every 2 weeks	Weekly*	Monthly
Oil application per† degradation month (kg/m^3/month) (max)§	167#	57	102#	14.7	36.8	3.4
Calculated weight percent of oil in soil (single application)**	13	4.4	8	0.58	10.0††	5.0††
Reported weight percent of oil in soil (percent)	2	4.6	-§§	-	***	-
Method of waste application	Spraying	Surface spreading by gravity	Surface spreading	Surface spreading and spraying	Subsurface injection	Surface spreading
Amendments added to soil	NPK	None	None	NPK + lime	K, lime,	Lime +

*Usually approx. 2 acres are injected in any one day. Frequency of waste application is reported frequency for maximum application rate.
†Per depth of incorporation.
§Based on maximum waste application rates reported.
#kg/m^3/yr.
**Based on reported waste application rates.
††Reported maximum target percentage of oil in the treatment soil.
§§Information not available.
***Section will not be injected until the oil content is less than 10 percent.

TABLE 6.
Operational Characteristics for Land Treatment Facilities 07-13

Parameter	Facility Code						
	07	08	09	10	11	12	13
EPA Region	VIII	V	VI	VI	X	VIII	IX
Treatment area (ha)	5.7	4.6	6.1	20	2.8	4.8	2.0
Zone of waste incorporation (depth, meter)	0.20	0.20	0.15	0.20	0.30	0.15	0.25
Reported waste application rates (maximum)	20815 kg waste/ha/ application	76118 kg waste/ha/ application	59.m^3 waste/ha/ application	3.5 kg oil/m^3/ application	772.kg/ waste/ha/ application	1050 kg oil/ ha/applica- tion	2.4 m^3 oil/ha/ application
Number of months site actively used per year	8	6	10	12	12	10	12
Frequency of waste application	Every 3 months	2 to 3 times/week	Monthly	Monthly	Monthly	Monthly	5 times/week
Oil application per* degradation month (kg/m^3/ month) max†	0.64	0.18	0.11	4.16	2.31	4.21	1.83
Calculated weight percent of oil in soil (single application)§	0.05	0.0036	0.8	0.28	0.18	0.34	0.35
Reported weight percent of oil in soil (percent)	-**	-	-	-	-	-	-
Method of waste application	Surface spraying/ spreading	Surface spreading	Surface spreading	Subsurface injection	Vacuum truck hose	Surface spreading	Surface injection
Amendments added to soil	Lime and fertilizer	Lime and fertilizer	Lime and (NPK) fertilizer	None	Lime and fertilizer (once in 3 years)	Lime and (NPK) fertilizer	None

*Per depth of waste incorporation.
†Based on maximum waste application rates reported.
§Based on reported waste application rates.
**Information not available.

range of values for biodegradation half-lives (site/soil characteristics), was to generate a matrix for evaluating the effect of design and site variables, and the interrelationships of these factors, on waste treatment.

The methodology used for calculating stabilized oil/soil concentrations is illustrated in Table 7. As indicated in Table 7 for Facility 05, using a 125 day half-life, 0.22 percent application rate, and a frequency of once every 7 days for 12 months, an oil/soil concentration value of 5.9 percent was predicted to occur after 1 year (week 52). After 5 years of continued use, the residual weight percentage of oil in the soil stabilized at 7.6 percent. Using a 304 day half-life value, the residual oil/soil concentration stabilized at 18.9 percent after 11 years of continued use (Table 8). Results indicated that the time required for a land treatment site to stabilize is primarily a function of the waste half-life, within the range of half-lives investigated, and to a lesser extent a function of the application weight percentage of oil in the soil. The calculated times required for treatment stabilization ranged from an average of 4 years to 15 years for 60 day and 304 day half-lives, respectively. Predicted stabilized oil/soil concentration values are presented in Table 8 for ten of the thirteen facilities.

The predicted values for stabilized oil/soil concentrations (Table 8), using the methodology described, agree well with the results obtained for several other full scale petroleum refinery land treatment facilities in the U.S. (10). Steady-state oil content in the zone of incorporation for full scale facilities reported by Brown (10) ranged from 3.5 percent to 8 percent.

A graphical representation of predicted stabilized residual oil/soil concentration values for eight of the thirteen facilities presented in Table 8 is shown in Figure 6. Waste degradation half-life is represented on the x-axis, waste application frequency is on the z-axis, and stabilized residual oil/soil concentration is on the y-axis. The family of curves represents different waste application rates. A three-dimensional form was used in Figure 6 to visualize the effect of waste application frequency and changes in application frequency on the stabilized residual oil/soil concentration values. For example, Facility 03 (identified as G in Figure 6), using a 304 day half-life, 8.0 percent application rate, and a frequency of once per year, resulted in a 5.3 percent stabilized residual oil/soil concentration. However, Facility 09 (identified as D in Figure 6), using the same half-life, 0.8 percent application rate, and a frequency of once a month for 10 months per year, resulted in a 13.8 percent stabilized residual oil/soil concentration value. Similarly for half-lives of 60 days, 125 days, and 146 days, stabilized residual oil/soil concentration values for Facility 09 were 9 fold, 4 fold, and 2.9 fold greater than Facility 03, respectively. Thus a 10 fold increase in waste application frequency resulted in a greater stabilized residual oil/soil concentration value even though the application rate was 10 fold less.

The interrelationships among waste application frequency, waste degradation half-life, and stabilized oil/soil concentration are illustrated in Figure 7 for an application rate of 0.3 percent oil in the soil and equal time intervals between waste application events. Matrices, such as Figure 7, may be useful as engineering aids for designing and managing petroleum land treatment facilities. An important parameter that may be managed is the waste degradation half-life. Pilot/bench scale studies can be utilized to evaluate half-life values for specific waste/site/soil management conditions (11). Waste application rates can be determined from the quantity of waste produced, waste oil concentration, and the land area required for actual treatment (see example in Table 7). Waste application frequency is a function of waste quantity and waste generation frequency. With any three of the four parameters known (half-life, application rate, application frequency, and stabilized residual oil/soil concentration), and assuming that half-life is independent of loading rate for the range of loading rates commonly used, the fourth parameter can then be determined.

Treatment area, waste incorporation zone, waste quantity applied, and waste application frequency are functions of the waste application rate and may also be obtained from Figure 7. For example, consider that a decision has been made, based on toxicity of the waste to soil microorganisms (5), to limit the stabilized residual oil/soil concentration to 5.0 percent. If bench scale tests

TABLE 7.
Example Calculations for Determining Values for Facility 05

Weight Percentage Oil in Soil Per Application	Fraction Reduction Determination	Residual Fraction Determination
Application rate x Treatment site area x (zone of incorporation) x ft^3 soil/80 lb (soil) x 100% - Application Rate Reported waste application rate x waste oil concentration [3 tons/acre x 2000 lb/ton] x 0.25 x acre/43560 ft^2 = 0.15 lb oil/ft^2 - Zone of incorporation 0.833 ft - Weight percentage oil in soil per application = 0.15 lb oil/ft^2 x (0.833 ft)$^{-1}$ x ft^3 soil/80 lb (soil) x 100% = 0.22%	$R^{\dagger} = (t_f/t_{1/2})x50\%$ - Half-life $t_{1/2}$ = 125 days - Waste application frequency t_f = weekly for entire year $R = (7/125)x50\%$ = 2.8% reduction	$C^{\dagger} = C_o{}^{\dagger}(1-R)$ Year 1-- Week 1) 0.22x(1-0.028)=0.214 2) 0.214 + 0.22 = 0.434 x (1 - 0.028) = 0.422% 3) 0.432 + 0.22 = 0.652 x (1 - 0.028) = 0.624% 52) 8.427 + 0.22 = 8.647 x (1 - 0.028) = 5.9% End of year 2) 7.2% 3) 7.5% 4) 7.6% 5) 7.6%

†Definitions:

R = percent oil reduction
C = residual weight percentage of oil in the soil (oil/soil)
C_o = waste application rate (oil/soil)

TABLE 8.
Predicted Stabilized Weight Percentage of Oil in Soil for Various Half-lives and Frequencies of Applications

Facility	Weight Percentage of Oil in the Soil Per Application (C_A)	Frequency of Waste Application	Predicted Stabilized Weight Percentage of Oil in Soil (C_s) at Various Half-lives ($t_{1/2}$)			
			$t_{1/2}$ (days)			
			60	125	146	304
01	0.36	Monthly for 6-7 months	0.2	0.8	1.0	3.1
02	4.36	Once per year	0.1	0.6	1.0	2.9
03	7.95	Once per year	0.1	1.0	1.8	5.3
04	0.58	Twice/month for 8 months	0.8	3.4	4.2	12.3
05	0.22	Weekly for entire year	3.6	7.6	9.0	18.9
06	0.27	Monthly for 12 months	0.8	2.0	2.4	5.2
07	0.05	4 times/year	0.03	0.08	0.1	0.3
09	0.80	Monthly for 10 months/year	1.1	4.1	5.2	13.8
12	0.34	Monthly for 10 months/year	0.5	1.6	2.0	5.0
13	0.35	Weekly for 52 weeks/year	5.7	12.2	14.2	30.0

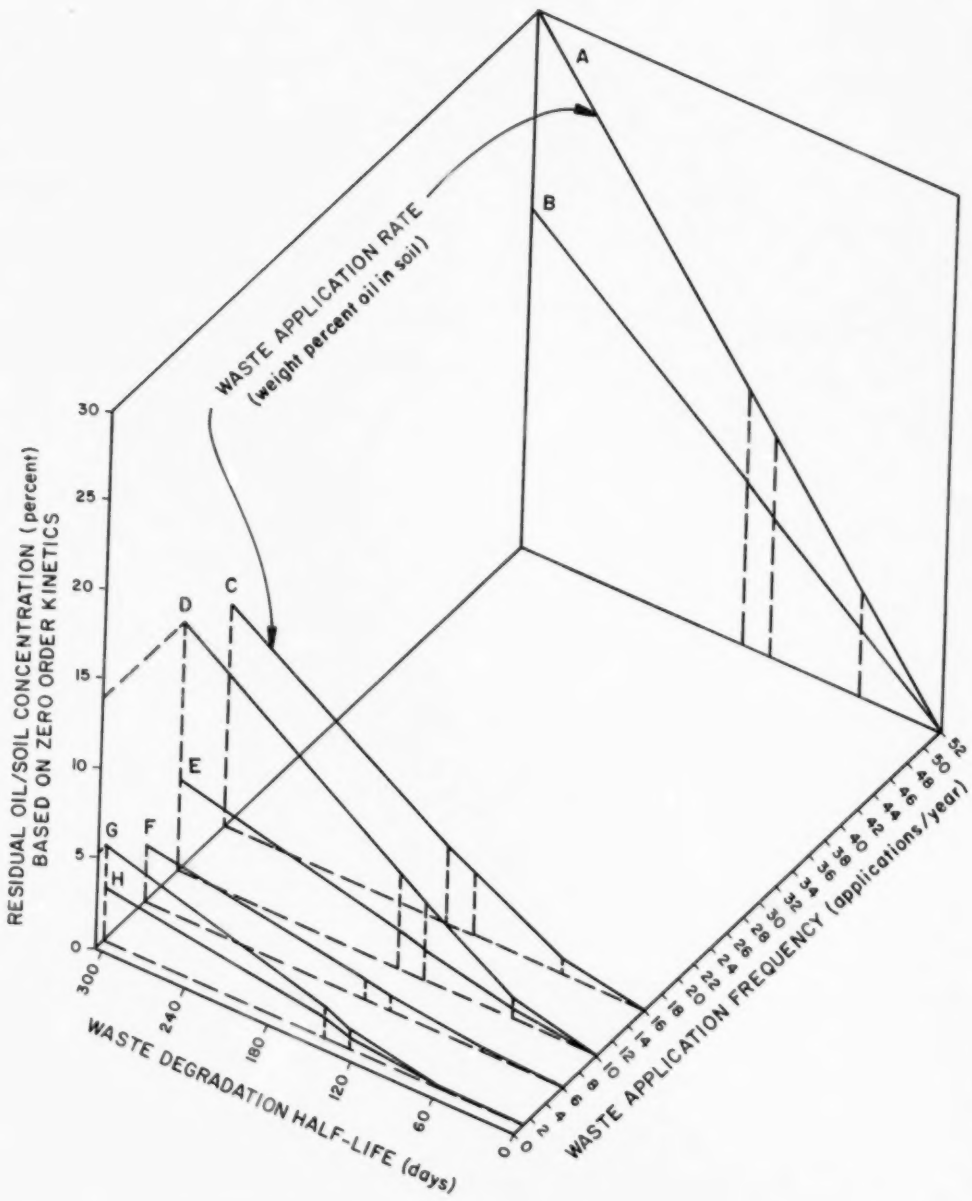

FIGURE 6. Facility Residual Oil/Soil Concentration as a Function of Waste Degradation Half-Life, Waste Application Frequency from Table 8, and Waste Application Rate. Waste Application Rate (Weight Percent Oil in the Soil) Key: A) 0.35%, B) 0.22%, C) 0.58%, D) 0.80%, E) 0.34%, F) 0.36%, G) 7.95%, and H) 4.36%

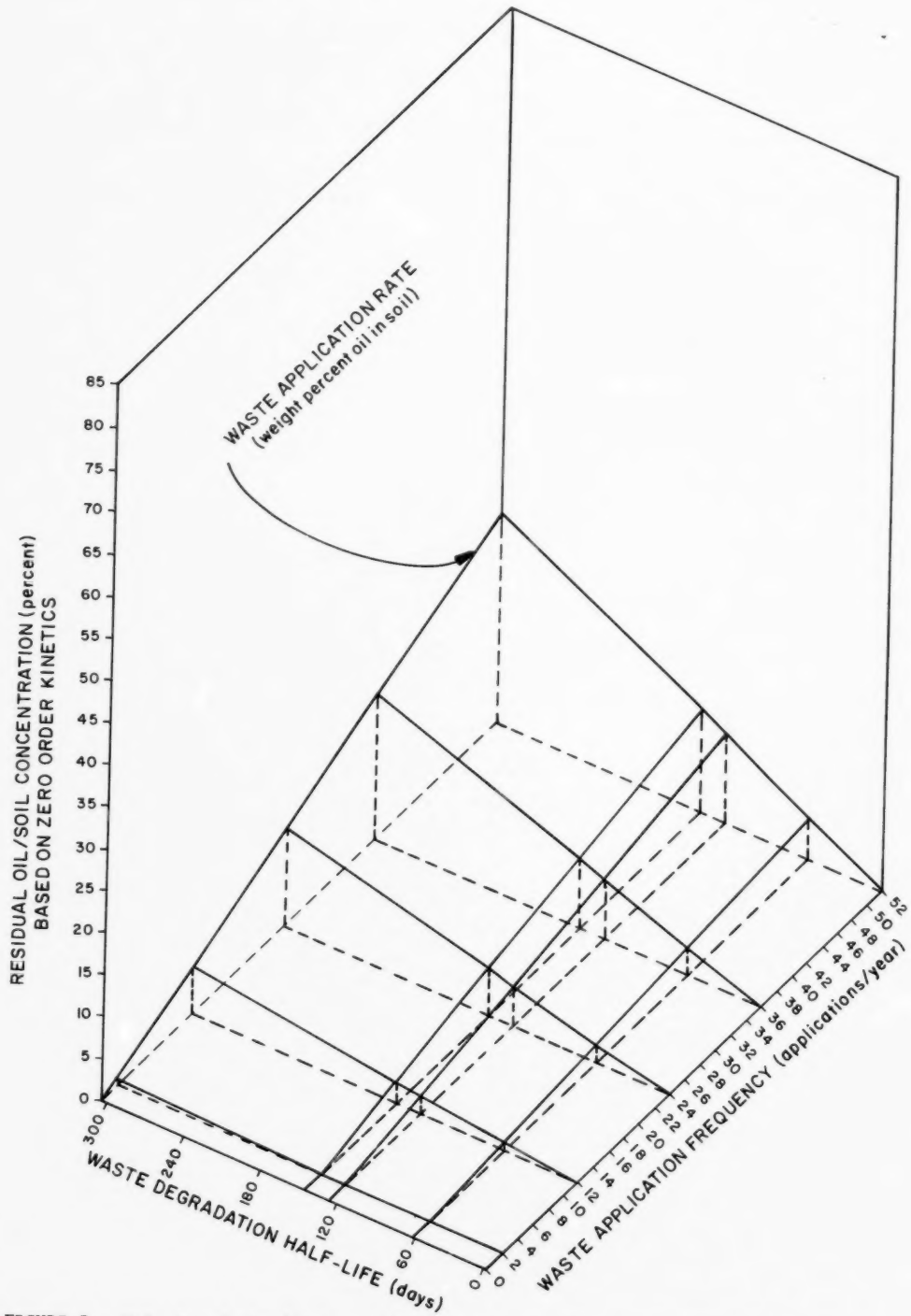
RESIDUAL OIL/SOIL CONCENTRATION (percent)
BASED ON ZERO ORDER KINETICS
WASTE APPLICATION RATE
(weight percent oil in soil)
WASTE DEGRADATION HALF-LIFE (days)
WASTE APPLICATION FREQUENCY (applications/year)

FIGURE 7. Calculated Residual Oil/Soil Concentration as a Function of Waste Degradation Half-Life, Waste Application Frequency, and 0.3 Percent Waste Application Rate

indicate a 146 day waste degradation half-life, from Figure 7, a frequency of 24 applications per year using a 0.3 percent waste application rate will provide the targeted stabilized residual oil/soil concentration value. By using the calculations presented in Table 7, values for treatment area, waste incorporation zone, and waste quantity applied can be determined.

SUMMARY

Information related to U.S. EPA regulations pertaining to petroleum land treatment practices was obtained from thirteen full-scale land treatment facilities. Specific information included types of waste land treated, characterization of land treated wastes, waste application rates, waste application frequencies, and waste management practices used at the treatment units.

From this information, waste oil degradation, in terms of stabilized weight percentage of oil in the treatment soil during the active life of the units (oil/soil concentration), was evaluated as a function of waste degradation half-life, waste application frequency, and waste application rate. A methodology was used to develop a three-dimensional graph to visualize the interrelationships of these parameters and the effects these parameters have on stabilized oil/soil concentration. Predicted values using the methodology agreed well with results obtained for full scale petroleum land treatment facilities in the U.S. It appears that waste degradation half-life and waste application frequency have a greater influence in determining stabilized oil/soil concentrations than waste application rate.

An additional three-dimensional graph was presented as an example engineering/management aid. The graph illustrates the relationships, for a constant waste application rate, among waste degradation half-life, waste application frequency, and residual oil/soil concentration. Also, site treatment area, waste incorporation zone, and waste quantity can be calculated from the three-dimensional graph.

RECOMMENDATIONS

This paper provides information regarding the practice of managing petroleum refinery wastes at land treatment facilities. More detailed information, including on-site observation and sampling, would be required to determine how effectively these wastes are being treated, any adverse environmental impacts, and justification for a particular treatment approach. Additional information is needed pertaining to the quality and quantity of waste organic hazardous constituents in oil waste, the actual quantity of each waste that is applied, the frequency of waste application, and procedures used for the application of wastes that are stored at a facility during inactive periods. The weight percentage of oil in the soil prior to each waste application and at intervals of time is required in order to calculate oil degradation rates, half-lives, and oil concentrations in soil as a function of time. Concentrations of specific organic hazardous constituents in soil before and after waste applications are also needed to calculate concentrations and degradation rates for each specific constituent of concern.

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